CRNA DNP Project: ECG Lead Placement in The Perioperative Setting

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Abstract

Proper electrocardiogram (ECG) placement is an important aspect of reliable cardiac monitoring during the perioperative period. Inaccurate and/or inconsistent ECG lead placement has the potential to lead to incorrect, missed, or delayed diagnoses, which may lead to unnecessary interventions and poor patient outcomes. Misplacement of electrodes may result from limited provider knowledge and the lack of continued education reinforcing proper placement. This Doctorate in Nursing Practice project assessed the perceived efficacy of a reference tool designed to streamline ECG lead placement and increase consistency across all disciplines in the perioperative setting. The ECG lead placement education included standard 6-lead and 12-lead placement. This reference tool, along with a PowerPoint presentation, was given to six preoperative nurses to use in their daily practice. Data gathered from the pre- and post-intervention surveys suggests that the reference tool was perceived to be effective in increasing knowledge of accurate ECG lead placement. Participants reported increased perceived confidence levels in accurate placement, decreased incidence of artifact/incorrect morphology in their monitoring, increased likelihood of fixing incorrectly placed ECG leads, and improved quality of the care provided to their surgical patients. ECG lead education projects such as this one should continue to be translated into clinical practice to improve patient outcomes related to ECG lead placement.

Keywords: ECG, perioperative period, patient outcomes, preoperative nurses, education

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Section I. Introduction

Background

The modern electrocardiogram (ECG) is one of the most common cardiovascular diagnostic tools used in clinical settings. The ECG is a computerized analysis of the signals from electrodes placed on the skin which measures electrical activity in the cardiac cycle (Kligfield et al., 2007). These electrodes, commonly referred to as leads, must be applied in specific configurations to accurately capture the differences in voltage of myocardial cells that take place during depolarization and repolarization. Inaccurate ECG lead placement and inadequate signal quality can lead to misdiagnosis, unnecessary procedures, and increased length of hospital stay (Fidler, 2014). Since obtaining an accurate ECG waveform is vital to appropriate diagnosis as well as subsequent clinical interventions, research surrounding this topic has focused on the proper placement of ECG leads and limitation of artifact.

Proper ECG lead placement is an important aspect of reliable cardiac monitoring during the perioperative period. Schroder (2016) describes ECG monitoring as an essential aspect of the anesthesia workplace, specifically in the early assessment of perioperative complications. In order to have proper interpretation of ECG monitoring values, the clinician must have an understanding of the functions, principles, and limitations of the process. Healthcare staff who are involved in placing ECG leads during the perioperative period are nurses, certified nursing assistants, certified registered nurse anesthetists (CRNAs), anesthesiologists, and cardiac technicians.

The standard 12-lead ECG consists of three categories of leads: limb leads (leads I, II, III), augmented limb leads (aVR, aVL, and aVF), and precordial leads (V1-V6). The standard 5-lead ECG (used in continuous monitoring) consists of the right arm (RA), left arm (LA), right leg

(RL), left leg (LL) and V1 leads. The current recommendations for the 12-lead electrode placement are as follows: four limb lead electrodes, with one distal to each shoulder and one distal to each hip, and six chest electrodes; V1 at the fourth intercostal space at the right sternal border, V2 at the fourth intercostal space at the left sternal border, V3 midway between V2 and V4, V4 at the fifth intercostal space in the midclavicular line, V5 in the horizontal plane of V4 at the left anterior axillary line, and V6 in the horizontal plane of V4 at the left midaxillary line (Medani et al., 2018). Current recommendations for 5-lead monitoring are as follows: RA lead directly below the clavicle and near the right shoulder, LA lead directly below the clavicle and near the left shoulder, RL lead on the right lower abdomen, LL lead on the left lower abdomen, and V1 lead is at the fourth intercostal space at the right sternal border (Kligfield, 2007). Alternative placements may be required due to body habitus, patient/surgical positioning, and surgical dressings.

The American Association of Nurse Anesthesiology (AANA, 2019) has created 14 standards for nurse anesthesia practice that are used to promote the delivery of high-quality and patient centered anesthesia care. Standard IX, or the monitoring standard, describes the importance of continuous monitoring throughout the perioperative period. This includes ventilation, oxygenation, heart rate/cardiovascular status (using electrocardiography), thermoregulation, and neuromuscular status. The American Society of Anesthesiologists (ASA, 2020) also promotes standards that encourage high-quality patient care. Standard 2.3 promotes the importance of ensuring patients have adequate circulatory function during administration of anesthetics. It states that every patient receiving anesthesia should have a continuous display of their electrocardiogram from beginning to end of the anesthetic experience. The Anesthesia

Patient Safety Foundation (APSF, 2022) has listed safety priorities for perioperative patients, and discusses the use of continuous monitoring as a way to trend and prevent clinical deterioration.

Efforts to improve ECG lead placement address multiple aspects of the Quadruple Aim (Bodenheimer & Sinsky, 2014). Improvements have the potential to reduce the cost of care and improve patient experience by decreasing costly medications, interventions, and/or procedures which may be instituted based on inaccurate ECG diagnoses.

Organizational Needs Statement

The partnering organization is a large medical center serving a primarily rural population of over a million people. ECG monitoring is frequently utilized during patient care and consistently implemented perioperatively. Though there are no current local, state, and/or national metrics addressing ECG lead placement issues, and no statistics specific to the organization, there is inherent ongoing risk associated with the care routinely provided.

Incorrect ECG lead placement has the potential to lead to incorrect analysis and diagnoses and result in unnecessary treatments that may be costly and painful for the patient (Medani et al., 2018). Incorrect ECG lead placement has led to patients inappropriately receiving medications, mechanical interventions (CPR, precordial thumps), and surgical implantation of permanent pacemakers and cardioverter-defibrillators (Fidler, 2014). Inaccurate diagnoses based on incorrectly applied ECG leads can affect patient outcomes, satisfaction scores, and insurance reimbursement. Currently, there are no educational initiatives or visual tools being utilized in the surgical areas of this organization to facilitate proper ECG lead placement. Incorporating current educational resources and visual aids may be useful in improving practice, particularly in cases where alternative placement may be necessary due to patient positioning or site limitations. The partnering organization has the potential to benefit from efforts to prevent inaccurate lead placement. This quality improvement (QI) project was designed to address this problem by providing a standardized educational aid focused on proper ECG lead placement.

As the AANA, ASA, and APSF organizations have clearly outlined the need for continuous and accurate monitoring as a standard of the anesthesia care model, this project's aims to enhance provider knowledge on this topic reflect their priorities. The potential for education regarding proper ECG lead placement to improve practice intersects with the goals of anesthesia groups by enhancing provider knowledge, which ultimately leads to more accurate monitoring.

Problem Statement

Inaccurate and/or inconsistent ECG lead placement in the perioperative period has the potential to lead to incorrect, missed, or delayed diagnoses. This may lead to unnecessary interventions and poor patient outcomes. Misplacement of electrodes may result from limited provider knowledge and the lack of continued education reinforcing proper placement.

Purpose Statement

This Doctorate in Nursing Practice project attempted to assess the perceived efficacy of a standardized educational aid designed to streamline ECG lead placement and increase consistency across all disciplines in the perioperative setting. ECG lead placement education included standard 6-lead and 12-lead placement.

Section II. Evidence

Description of Search Strategies

The PICOTS (problem, intervention, comparison, outcome, time, setting) question used to guide the review of existing literature was: How do educational resources regarding traditional and alternative ECG lead placements affect the perception of healthcare providers in their ability to correctly place ECG lead configurations in surgical patients during the perioperative period? The main concepts used in this search, shown in Appendix A, were *ECG lead placement, healthcare providers,* and *education.* Structured searches were completed in the scholarly databases Medline PubMed and Cumulative Index to Nursing and Allied Health Literature (CINAHL), as well as the search engine Google Scholar, to identify pertinent literature.

In PubMed, the search strategy used was (ECG lead placement AND education AND (healthcare provider OR nurse anesthetist OR hospital personnel)). The limits originally applied were peer reviewed and 2017-2022. Due to minimal results, the year range was extended to 2007-2022. Fourteen total articles were found with these limits, and ten were kept after screening for potential relevance based on title and abstract. The articles were then reviewed for relevance to topic, level of evidence, strength of results, and lack of bias. The references of the articles were reviewed, with many of the references being other articles that populated from the previously named search strategy. After this full review, eight articles were kept.

In CINAHL, the search strategy used was ((MH “Electrodes”) OR (MH “Electrocardiography”) OR “EKG lead placement”) AND ((MH “Health Personnel”) OR (MH “Anesthesia”) or (MH “Anesthesia Nursing”) OR (MH “Nursing Staff, Hospital”) OR (MH “Nurse Anesthetists”) OR (MH “Anesthetists”)). The limits applied were peer reviewed and 2012-2022. The search resulted with 132 articles, but none were used in this literature synthesis due to the limited relevance of the findings. With Google scholar, the search strategy used was the same as PubMed. The filters applied were review articles and 2021-2022. The search yielded 1270 results, of which the first 10 pages were searched. Throughout the articles searched, none were relevant to this topic. Websites of professional organizations were also searched. This literature search log information is compiled in Appendix B.

The levels of evidence of these articles were reviewed according to the Melynk and Fineout Overholt (2019) hierarchy of evidence framework. One systematic review (Level I), two randomized controlled trials (Level II), five nonrandomized controlled trials (Level III), one controlled cohort study (Level IV), two descriptive studies (Level VI), and five expert opinions (Level VII) were identified and deemed pertinent to this project. A literature matrix, as described in Appendix C, was created to compile information about the above sources.

Selected Literature Synthesis

The literature synthesized in this review focuses on the current evidence regarding ECG lead placement, education regarding proper placement, and complications associated with incorrect lead placement. In the results of identified studies, authors suggested a lack of clinician knowledge as the largest barrier to electrode placement (Fidler, 2014; Giannetti et al, 2020; Ide, 1995; Kligfield et al., 2007; Medani et al., 2018; Rajaganesh et al., 2008). Clinicians may be unfamiliar with specific anatomical markings related to proper ECG lead placement. A landmark study completed by Ide (1995) found that 87% of nurses utilized incorrect lead placement. Another study completed 13 years later showed knowledge regarding ECG lead placement still had room for improvement, reporting that 10% of cardiac technicians, 51% of nurses, 69% of non-cardiologist physicians, and 84% of cardiologists incorrectly identified proper ECG lead landmark sites (Rajaganesh et al., 2008). In 2018, a study was completed by Medani et al. in which the authors also reported the continued need for further education, finding an average of only 34% of correct lead placements across doctors, nurses, and cardiac technicians. In 2020, yet another study's authors determined that the need for continued education regarding ECG lead placement among nurses still persisted (Giannetta et al., 2020).

The most common error across these studies was the superior misplacement of the V1 and V2 electrodes (Garcia-Niebla et al., 2012). Physical barriers to proper ECG lead placement that have been identified included large breasts and excess subcutaneous tissue in the obese (Rajaganesh, 2008). Additionally, bony landmarks may not easily be identified, leaving the clinician to guess the correct lead position. Day et al. (2015) offered alternative methods for accurately placing ECG leads when anatomical landmarks are lost. Even when ECG leads are in the correct anatomical positions, the ECG results may still be compromised due to inadequate lead adherence to the patient's skin (Fidler, 2014).

Although modified lead configurations reduce artifact and increase patient comfort, several authors identified evidence to support the use of the standard 12-lead ECG for accurate diagnosis of cardiac abnormalities (Fidler, 2014; Kligfield et al., 2007; Lancia et al., 2008; Medani et al., 2018). However, in instances of unavoidable prone positioning (e.g., COVID-19 treatment, surgical positioning), the alternative prone ECG lead placement has been found to be reliably accurate when compared to the standard ECG lead placement (Romero et al., 2021; Sanchez et al., 2021). Additionally, in instances where standard ECG lead placement cannot be used (cardiac surgery, chest dressings, etc.), modified lead configurations have been implemented to provide similar recordings as an alternative to maintain accuracy for ECG analysis (Khan, 2015).

The clinical significance of proper ECG lead placement centers around the absence or incorrect detection of ECG abnormalities and the resulting interventions (Kligfield, 2007). Misplacement of precordial leads of as little as two centimeters can lead to diagnostic errors, specifically with anteroseptal infarctions and ventricular hypertrophy (Ilg & Lehmann, 2012; Kligfield et al., 2007; Medani et al., 2018). Additionally, misplaced leads can alter computer-based diagnoses up to six percent (Kligfield et al., 2007). Misplacement of V1 and V2 can reduce R-wave amplitude, causing decreased R-wave progression, altered QRS complexes, and altered T wave morphology, which can result in decreased accuracy of diagnosing anterior infarction. V5 and V6 are also commonly misplaced, which can alter amplitudes used in detecting ventricular hypertrophy (Medani et al., 2018.) Incorrectly placed ECG leads can result in false positive and false negative ischemic changes, while reversed electrodes may invert the QRS complex and cause unexpected Q-waves, R-waves, and markedly isoelectric leads (Sakaguchi et al., 2018).

Misplacement of ECG leads can also increase artifact that mimics arrythmias in ECG monitoring (Fidler, 2014; Ilg & Lehmann, 2012). Artifact causing atrial arrhythmia misdiagnoses, like pseudo-atrial flutter, has caused patients to be unnecessarily prescribed antiarrhythmic and anticoagulation medications (Fidler, 2014). Artifact that closely mimics ventricular tachycardia has also led patients to inappropriately receive medications, precordial thumps, and surgical implantation of permanent pacemakers and cardioverter-defibrillators.

Overall, authors found current evidence that a lack of clinician knowledge, large body habitus, and inappropriate configuration techniques all contributed to misplaced ECG leads, which may result in incorrectly detected or missed cardiac abnormalities and inappropriate treatment. (Fidler, 2014; Giannetti et al, 2020; Kligfield et al., 2007; Medani et al., 2018;

Rajaganesh et al., 2008). Since ECG technology continues to be widely utilized in cardiovascular diagnosis, the need for optimization of ECG lead placement is an important issue, especially in perioperative patients.

Current evidence supports the use of educational trainings to increase clinician knowledge and accountability in the proper placement of ECG leads (Funk et al., 2017; Dilibero et al., 2016; Medani et al., 2018; Rajaganesh et al., 2008). The goal of this DNP project followed the recommendations of the literature in this author's attempt to increase provider awareness regarding proper ECG lead placement.

Project Framework

The framework used for executing this project was the Institute for Health Improvement (IHI, 2022) model for improvement using a single plan-do-study-act (PDSA) cycle. It consists of four steps and is particularly helpful when one is working with single interventions, short durations, and small sample sizes. The first step (plan) is to plan the test or observation, which includes planning for the process of gathering data and the subsequent intervention. The second step (do) is to practice the test on a small scale and document any problems or unexpected results. The third step (study) is to analyze the data, compare it to the predicted results, and reflect on what was learned. The fourth step (act) is to make necessary modifications based on what was learned from the previous step, and prepare a plan for the successive test.

This cycle was useful for this project in that it aided in quickly testing a change made on a small scale. Step one was to plan out the educational tool regarding ECG lead placement that was given to perioperative nurses, as well as the initial and follow-up surveys that were used for data collection. The second step was to give the nurses the pre-intervention survey, the educational tool to utilize for two weeks, and the post-intervention survey. The third step was to analyze and compare the data collected from the two surveys, in the hopes that the second survey would demonstrate that use of the tool would increase perceived knowledge of ECG lead placement. The final step was to determine necessary modifications to the surveys and education tool and then suggest how they could be utilized on a larger scale.

Ethical Considerations and Protection of Human Subjects

There were no specific ethical concerns related to this project, with little risk assumed as the intervention consisted of a simple educational tool and questionnaires to collect answers regarding the opinions and perceptions of the participants. As incorrect ECG lead placement can lead to unnecessary patient costs and treatments as well as increased cost for the hospital. the benefit of implementing this tool outweighed any minimal risk that might result from the intervention. The intervention applied equitably to the target population of perioperative nurses working in the preoperative unit of the involved organization.

Preparation for the formal approval process included completion of assigned Collaborative Institutional Training Initiative (CITI) modules (https://about.citiprogram.org/). The preliminary approval process was completed through the East Carolina College of Nursing and the East Carolina University and Medical Center Institutional Review Board (UMCIRB) through which the project was determined to meet criteria as quality improvement and thus exempt from full IRB review. The project was additionally approved by a process through the participating organization and the UMCIRB which included a requirement for a signed document from a representative in the unit where data collection was to take place. This review also resulted in a determination of quality improvement and was approved without issues (see Appendix D).

Section III. Project Design

Project Setting

This project was performed in an almost 1,000 bed, level I trauma center located in the eastern United States. This medical system serves 29 rural counties surrounding the main hospital and averages about 27,000 surgeries per year. The specific unit participating in this project was the 22 bed Preoperative Unit (a part of the larger Post Anesthesia Care Unit [PACU] that is split between the preoperative and the postoperative sides). This portion of the unit takes care of patients in the immediate period before surgery. The preoperative nurses prepare the patients for surgery, place ECG electrodes for monitoring when regional anesthesia is given before surgery, and monitor ECG status after intravenous adjuncts have been administered. The ECG lead placement in surgery may require alternative positions due to surgical sites or surgical positioning, and these pre-operative nurses can help to place the leads in the appropriate positions. The project was implemented in the summer of 2023. A facilitator for this project setting was the hospital system's close partnership with the university nearby. Additionally, this hospital system is a teaching hospital, so the staff are familiar with the research-driven approach to learning. There were no known barriers specific to this setting.

Project Population

The project population was preoperative nurses in the PACU at the partnering facility. These nurses have either associate or bachelor's degrees in nursing. There are approximately 50 RNs working in the PACU, not including travel nurses. A fully-staffed day for the PACU includes 63 nurses. A facilitator to working with this population was that the staff are familiar with the research-driven approach to learning. Two primary barriers to working with this population were identified. First was the large number of travel nurses working on the unit, as they may have had less buy-in than permanent staff nurses in participating in this project.

Second, staff nursing turnover rates have increased in the last five years, with the most recent data showing a yearly 30% turnover rate in North Carolina (Nursing Solutions, Inc, 2022). Some nurses on this unit were new hires, new graduates, or nurses leaving the job. These populations may be less motivated to participate in a quality improvement project.

Project Team

The project team consisted of four SRNA students, two nurse anesthesia faculty members, and the clinical setting contact person. The author was the primary investigator and worked with three other students to design the project. Each of these students implemented a similar project with other staff at the hospital (Cardiovascular ICU [CVICU] nurses, Cardiac ICU [CICU] nurses, and CRNAs). The project chair was a university professor who helped to plan, implement, and complete the DNP projects. There was also a site contact person (the manager of the perioperative services) who aided in the facilitation of data collection. Also involved in the project were a clinical contact member of the project team who assisted in the implementation of the project in the clinical setting and the program director who helped identify units for implementation of the DNP projects. The final member of the project team was the course director who supported literature review and analysis, DNP project implementation, and data collection and analysis. This member also reviewed and supported development of this paper.

Methods and Measurement

The purpose of this quality improvement project was to assess the perceived efficacy of a standardized reference tool designed to streamline ECG lead placement and increase consistency of ECG lead placement knowledge among nurses in the preoperative setting. The intervention was to provide a reference tool to PACU nurses and measure its efficacy over a two-week period. The information was provided to participants via a QR code on a flyer placed in the pre-operative nurses' breakroom (Appendix E). This QR code linked to the following: the reference tool in a PDF file (Appendix F), pre- and post-intervention surveys (Appendix G), and a brief recorded presentation (Appendix H) of the project background and reference tool use. Prior to and following this two-week period, the participants filled out the Qualtrics surveys (Appendix G), which were used for data collection. The self-reported outcomes assessed the participants' perceptions of the efficacy of the ECG reference tool, and if it improved their practice of placing ECG leads in the clinical setting.

Implementation Plan

After identifying the DNP topic of ECG lead placement along with three other students, a literature review was performed, and the planning phase of the PDSA methodology began. Major points were identified in the literature, including the need for increased/continuing education regarding ECG lead placement. Consequently, the project was created around the goal of increasing knowledge of proper ECG lead placement. The implementation of a reference tool to increase the project populations' knowledge of ECG lead placement was discussed, and a pre- and post-intervention survey to help measure the outcomes was planned. Target populations selected were health care providers directly involved in the care of perioperative patients.

The four target populations included CVICU, CICU, preoperative nurses, and CRNAs. Each student focused on a different population and individually gathered information about their respective unit. This DNP project focused on the preoperative nurse population. Approval was sought from a unit representative, the participating facility, and the IRB approval board. The reference tool was created based on recommended guidelines regarding ECG lead placement. A recorded presentation was also created which discussed the QI project and the reference tool.

Finally, the pre- and post-intervention survey questions were written. These questions focused on providers' confidence in placing ECG leads, how often they experienced artifact/incorrect morphology, and how often they received patients who had incorrect lead placement. The survey tool included Likert-type scale and free response questions. This provided quantitative as well as qualitative data. The next step of the PDSA methodology then began, which was the *do* part of the cycle.

The pre-intervention survey (Appendix G), recorded presentation explaining the project, and the reference tool were provided, via QR code, to all preoperative nurses. Participation was voluntary, and those who filled out the survey became the subject sample. The ECG lead placement reference tool was a PDF file included in the QR code links. The tool was then to be used by the participants for two weeks in their daily practice. The same QR code was again used by participants to access the post-intervention survey (Appendix G). This survey also included a free-response section where participants could offer critique or suggestions regarding the intervention. To increase participation in the project, the initial two week implementation time was extended to three weeks. The next step of the PDSA methodology, *study*, then began.

The data from both the pre-intervention and post-intervention Qualtrics surveys were collected and compared to analyze the relationship between the reference tool and the effect of perceived increased knowledge of ECG lead placement. The project then moved to the *act* phase of the PDSA methodology, during which opportunities for improvement were discussed and developed, and the results shared with participants and others.

Section IV. Results and Findings

Results

This DNP project attempted to assess the perceived efficacy of a standardized educational aid designed to streamline ECG lead placement and increase consistency across all disciplines in the perioperative setting. ECG lead placement education included standard 6-lead and 12-lead placement. The target population of this project was preoperative nurses. A QR code given to this population included links to a pre-intervention survey, a PDF reference tool, a brief voiceover presentation discussing the project and the tool, and a post-intervention survey. The outcomes were the participants' perceptions of the efficacy of the ECG reference tool and if it improved their practice of placing ECG leads in the clinical setting. Six pre-intervention surveys and six post-intervention surveys were collected via Qualtrics. Data was analyzed using Excel.

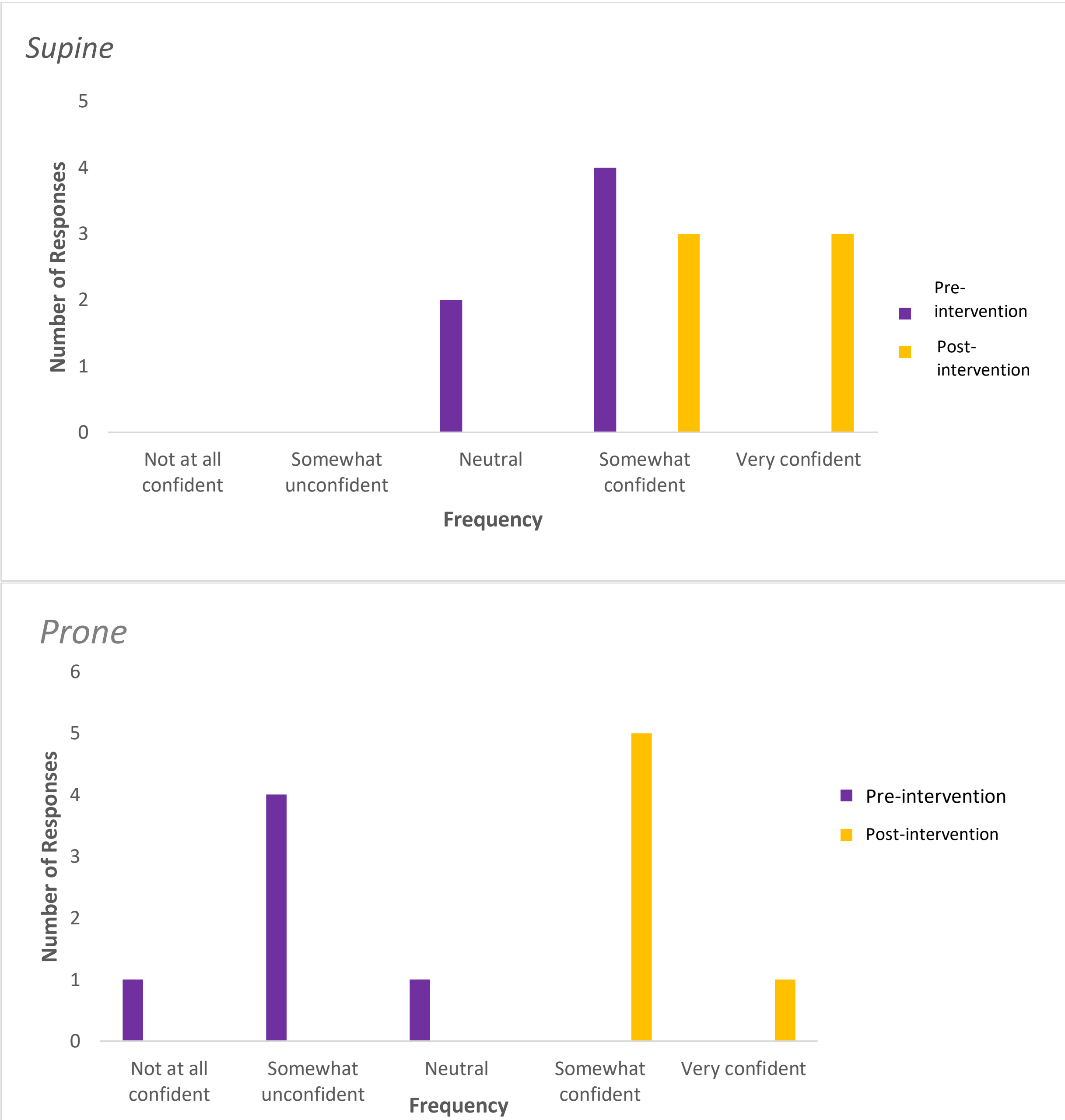
Data Presentation

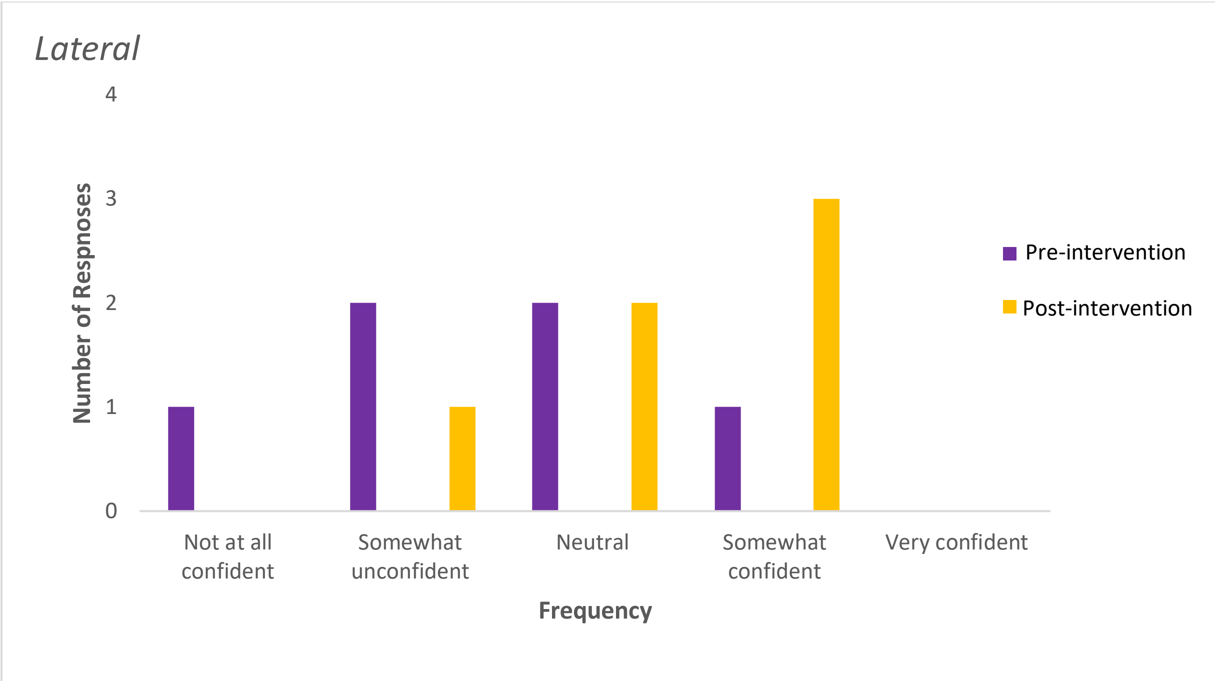
A total of 6 pre-intervention and 6 post-intervention questionaries were completed by the preoperative nurses in the facility. When responding to the question in the pre-intervention survey "Did you receive any formal training in ECG lead placement?", four participants responded *yes* while two participants said *no.* This question was posed to gain understanding of the level of training that participants previously had regarding the subject of ECG lead placement.

Another question asked of participants in both the pre-and the post-intervention survey was "How confident do you feel placing ECG leads in the following in standard and alternative positions: Supine, prone, lateral?". Figure 1 displays the data gathered from this three-part question.

Figure 1

Confidence Placing Leads in Standard and Alternative Positions (n=6)

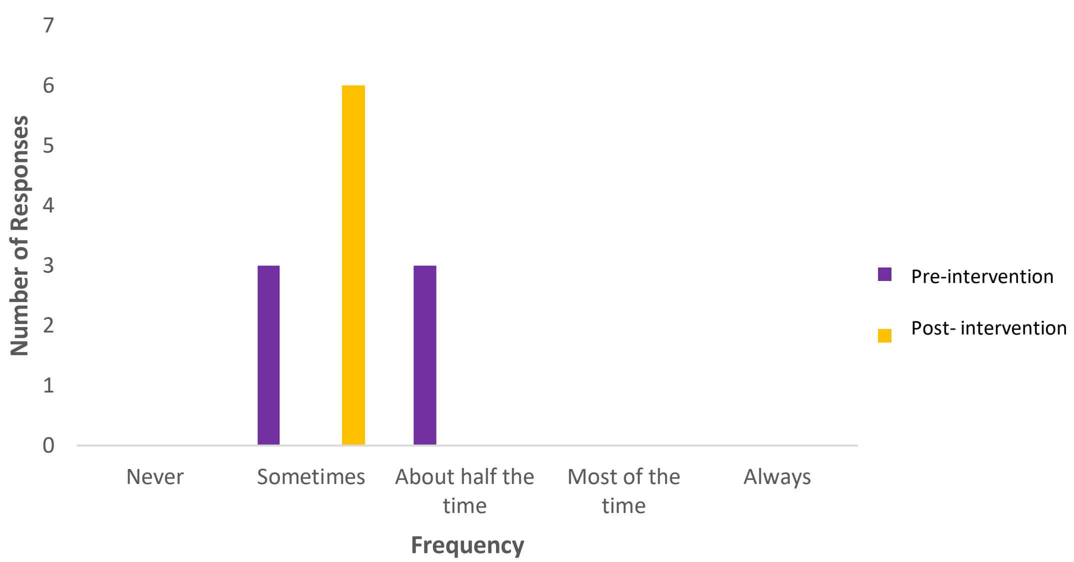



Lateral
4
3
2
1
0
Number of Respnoses
Not at all confident
Somewhat unconfident
Neutral
Somewhat confident
Very confident
Frequency
Pre-intervention
Post-intervention

The question "How often do you experience artifact or incorrect morphology with your current ECG lead practice?" was included on both the pre- and post-intervention surveys. Figure 2 displays the data gathered from this question.

Figure 2

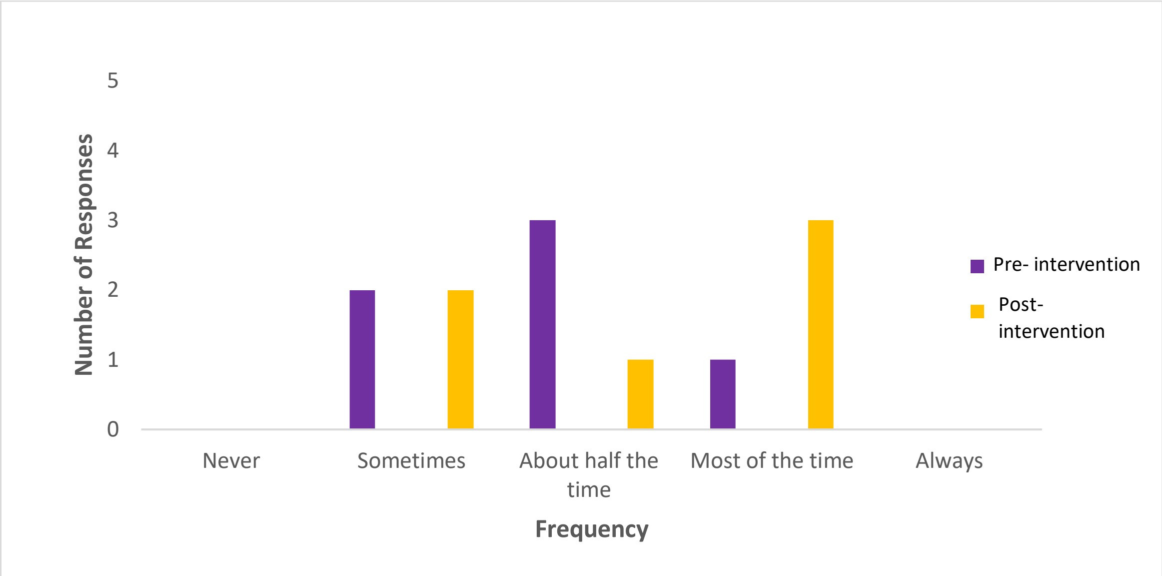
Experiencing Artifact/Incorrect Morphology in ECG Lead Practice (n=6)



The question "How often do you adjust ECG lead placement for body habitus, position, dressings, etc. to achieve an acceptable ECG tracing?" was also included on both the pre- and post-intervention surveys. Figure 3 displays the data gathered from this question.

Figure 3

Adjusting ECG Lead Placement to Achieve an Acceptable ECG Tracing (n=6)



In the pre-intervention survey, when asked "How often do you receive patients with inaccurate ECG lead placement?", one participant answered *sometimes,* four participants *about half the time,* and one *most of the time.* When asked "How often do you follow a standardized method for applying ECG leads?", one participant answered *about half the time,* four *most of the time,* and one *always.*

In the pre-intervention survey, "Do you believe the quality of patient care could be improved with more accurate ECG lead placement?" was asked. Four participants answered *probably yes* and two participants *definitely yes*. The post-intervention match to this question posed the statement "The ECG placement tool improved the quality of care I delivered my patients." Three participants answered *somewhat agree* and three participants answered *strongly agree.*

A final, free-response question in the pre-intervention survey asked participants "What are other obstacle to accurate ECG lead placement?". One answer was *obese patients, large breasts, and dressings.* Another answer was *works well enough even if placement is not perfect.*

To the post-intervention question "How likely are you to continue using the ECG placement tool when applying ECG leads in the future?", three participants answered *somewhat likely*, and three *extremely likely.* This question was posed to understand if the preoperative nurses would continue using the tool. When asked to respond to the post-intervention statement "The ECG placement tool was easily accessible," one participant answered *somewhat agree* and five *strongly agree.* This question was posed to determine if improvements could be made to the reference tool if it were to be used on a larger scale. When given the post-intervention survey question "How often did you use the ECG placement tool in your practice since receiving it?", one participant answered *sometimes,* one *about half the time,* three *most of the time,* and one *always.* This question was posed to understand how often the reference tool was being used.

When given the post-intervention question "About how much additional time did it take to reference this tool in your daily practice?", five participants answered *less than 1 minute,* and one answered *1-2 minutes.* This question was posed to determine how long it took to use the reference tool in clinical practice.

Analysis

Overall, after reviewing the data gathered from the pre- and post-intervention surveys it is suggested that the standardized educational aid was perceived to be effective in increasing knowledge of accurate ECG lead placement. In the pre-intervention survey, answers gathered regarding how often participants received patients with incorrect ECG lead placement, if they followed a standardized method for ECG lead placement, and if they received formal training in ECG lead placement supported the need for implementation of this ECG lead placement reference tool. Survey responses were reviewed and it was found that participants experienced less artifact/incorrect morphology and adjusted ECG lead placement more often after using the ECG lead reference tool. Participants in the project had increased confidence levels after using the ECG reference tool. Participants also felt that the ECG lead reference tool improved the quality of care for their patients, and they would be likely to continue using it in the future. Additionally, responses showed that participants felt the reference tool was easily accessible and could be referenced in less than one minute.

Section V. Implications

Financial and Nonfinancial Analysis

The literature synthesis completed regarding ECG lead placement showed that misplacement of ECG leads can mimic arrythmias that causes patients to unnecessarily receive antiarrhythmics, anticoagulant medications, precordial thumps, and surgical implantation of permanent pacemakers, and cardioverter-defibrillators (Fidler, 2014; Ilg & Lehmann, 2012). All of these interventions can increase length of stay and, according to KFF (2021), the average cost of one day as an inpatient in North Carolina can equate to around $2,573. Additional tests that could be performed due to misdiagnoses are cardiac computerized tomography coronary angiography ($406-$917), nuclear stress testing ($463-$3,230), diagnostic coronary angiograms ($657-$25,521) and cardiac catheterizations ($9,203; MD Save, 2023). In a study completed by the Commonwealth Fund in 2008 to discover how much hospitals absorb the cost of medical errors, authors found that the average cost per patient injury was $58,766 for adverse events and $113,280 for negligent injuries. On average, hospitals absorbed 78% of the costs of all injuries and 70% of the cost of negligent injuries. Medical errors can be costly, and implementing a project that may decrease unnecessary treatments could potentially save money for both patients and hospital systems.

Implementation of this project did not involve any financial cost as the ECG reference tool was a free PDF and the student implementing the project was not an employee of the hospital. If it were to be implemented on a larger scale by an employee of the hospital, costs would include the salary of the employee/employees during the periods of development and implementation. According to Indeed (2023), the average registered nurse salary in North Carolina is $40.31 per hour. Assuming there would be a staff of two employees, over one 40-

hour week development period and two 40-hour week implementation period, this would be an estimated cost of $9,000. Additional in-person education for ECG lead placement could help to further increase knowledge of correct ECG placement amongst healthcare providers. This would involve additional costs of mannequins/supplies for education. There would be no increased risk to patients related to the implementation of this project as it is educational in nature and would only improve ECG lead placement. Considering the costs of an average nursing salary and of training supplies, it is estimated that a three-week development/implementation period would cost roughly $10,000. This cost is still significantly less than the cost of the hospital covering a single adverse event of a patient related to misplaced ECG leads.

A resource that added to a successful outcome of this project was the unit manager who helped make suggestions for how best to make the staff aware of the project as emails, the originally planned method of information delivery, are not routinely checked by these nurses. A barrier to a successful outcome was the limited amount of face-to-face interaction time the author had with potential participants to raise awareness of the project due to education and clinical commitments. Hospital employees implementing this project may not have the same barriers to replicate this project.

The benefit of the project is the potential to decrease costs associated with adverse outcomes and unnecessary testing. As authors of the Commonwealth Fund (2008) discussed, average cost per patient injury was $58,766 for an adverse event and $113,280 for a negligent injury. Implementing a comparatively inexpensive project to increase efficiency and accuracy of ECG lead placement would yield a solid return on investment if the project decreased even one instance of a negative patient outcome due to incorrect lead placement.

Implications of Project

Standard IX of the AANA's standards, or the monitoring standard, describes the importance of continuous monitoring throughout the perioperative period. This project addresses this standard by focusing on the importance of proper ECG lead placement, which allows for accurate continuous monitoring. Standard 2.3 of the ASA's standards (American Association for Nurse Anesthesiology, 2019) states that every patient receiving anesthesia should have a continuous display of their electrocardiogram from beginning to end of the anesthetic experience. Again, this project addresses this standard by ensuring proper ECG lead placement in the preoperative area for accurate use during anesthesia. The APSF has listed safety priorities for perioperative patients and discusses the use of continuous monitoring to trend and prevent clinical deterioration. This project also addresses this safety priority. Additionally, this QI project addresses the Quadruple Aim through its goal of increasing education regarding proper ECG lead placement, which has the potential to reduce the cost of care and improve patient experience by decreasing costly medications, interventions, and/or procedures that may be instituted based on inaccurate ECG diagnoses.

Findings from this project echo findings in the literature that discuss the effectiveness of using clinical education as a means to improve knowledge of ECG lead placement. Increasing awareness of correct ECG lead placement in the pre-operative area sets the patient up for more accurate continuous monitoring once they are in the intraoperative setting. This project demonstrates an integral part of nursing practice where the primary focus will always be to provide safe, quality patient care. Any steps that can be taken to improve patient outcomes should be used in everyday practice, and the use of the ECG lead reference tool can be one of those steps. Though this project may have been on a small scale, health organizations should be aware of how even small projects like this one can have a positive effect on both patients and staff. Nursing staff feel proud when they can improve the quality of their care, and patients can trust that they will have safe, continuous monitoring in the perioperative setting.

Sustainability

If the organization were to use this pilot study to implement a larger QI project, cost would not be a problem. The implementation of this project could be free, as it only consists of the use of a free PDF tool that participants can download on their phones. If participants reference the ECG lead reference tool before placing the leads, there is potential for saving money on electrodes because the need to switch them out or change wrong placement around would be decreased. The reference tool could be used indefinitely, as long as the user keeps it downloaded on their phone and the information remains current. There would not need to be an end-point, as ECG lead placement can always be refreshed and improved.

A possible issue with sustainability is that after several times of using the reference tool users no longer need to use it to be aware of proper ECG lead placement. However, this addresses the goal of the project in the first place. This QI project could be implemented in any unit with continuous monitoring. Additional QI projects could include in-person training with mannequins and ECG leads, and working with surgeons to know what their prep-sites will be for specific surgeries so that alternative ECG lead placements could be worked out in the preoperative setting. As a project with no overhead costs and minimal effort on the part of the participant, it could easily be implemented in multiple departments throughout the healthcare organization.

Dissemination Plan

A poster was created showing the details of this DNP Project, and was then presented to the CRNA department members. Project participants were invited to attend. The presentation could be viewed in person at the University's College of Nursing building or online via a live video link. The final version of this paper and the presentation poster were posted in The Scholarship, the East Carolina University digital repository.

Section VI. Conclusion

Through the literature synthesis completed in the beginning stages of this project, it was supported that education on correct lead placement is an effective way to improve the accuracy of clinicians' practice in placing ECG leads. It was also suggested from the literature that, prior to receiving clinical education, almost all clinicians had room for improvement in the accuracy of their ECG lead practice. The clarity of the findings from the literature review provided the basis for this DNP Project.

The project assessed the perceived efficacy of a standardized educational aid designed to streamline ECG lead placement and increase consistency across all disciplines in the perioperative setting. Analysis of the results from the pre- and post-intervention surveys showed that an ECG lead reference tool increased participants' perceived confidence levels in accurate placement, decreased incidence of artifact/incorrect morphology in their monitoring, increased the likelihood of fixing incorrectly placed ECG leads, and improved the quality of the care provided to their surgical patients. Per the data found in the literature review, ECG lead education projects such as this one should continue to be translated into clinical practice to improve patient outcomes related to ECG lead placement.

Limitations

This project faced several limitations. First, the sample size was small and consisted of only six participants. Second, as survey results were anonymous, there was not a way to match up responses between pre- and post-intervention surveys. Additionally, there was not a way to know that it was the same six participants for each survey. Another limitation was that the project only focused on ECG lead placement, and not ECG monitoring. The level of expertise in reading ECG waveforms cannot be assumed, which may or may not have affected participants'

ECG lead placement. Other limitations were that this was self-reported data as opposed to quantitative data, and that the project timeline only lasted three weeks.

Recommendations for Future Implementation and/or Additional Study

If this project were to be recreated, a few adjustments would assist with implementation. First, it may be helpful to choose a population that is easily accessible by email. As the population in this project was not easily reached by email, a change in plans was created to provide the information by using a QR code on a flyer in the break room (see Appendix F). Thus, the choice to participate in the project depended highly on noticing the flyer. Secondly, a stronger physical presence with the participants during implementation may prove to be useful. Although the creator of this project made a concerted effort to speak to many possible participants, a continuous presence at specific intervals (e.g., change of shift) may prove to be useful in recruiting and motivating participants. Evaluation of the results could also be accomplished through Qualtrics, rather than Excel, as it is a simple-to-use resource that also includes a data analysis function and has a minimal learning curve.

Although this project only measured the participants' perceived efficacy of the ECG lead reference tool in their clinical practice, the additional concept of providing education on accurate monitoring/interpretation of ECG waveforms could be further investigated. Receiving education on both ECG lead placement and ECG waveform monitoring would be a more comprehensive approach to improve patient outcomes. Additionally, this project focused only on participants' knowledge, and cannot support that patient outcomes were improved. For a larger, more applied project, patient outcomes should be included as one of the primary measures.

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Appendix A

Literature Concepts Table

	Concept 1: EKG lead placement	Concept 2: Healthcare providers	Concept 3: Education
Keywords	EKG leads Lead positioning Alternative placements	Staff Anesthesia Nursing	Staff guide Training User tool
PubMed MeSH	"electrocardiography" [MeSH Terms] And "lead"[MeSH Terms] And "electrode" [MeSH Terms]	"health personnel" [MeSH Terms]	"educational status" [MeSH Terms] And "teaching" [MeSH Terms]
CINAHL Subject Terms	"Electrodes" "Electrocardiography"	"Medical Staff, Hospital" "Nurses" "Operating Room Personnel" Physicians"	"Education"
Google Scholar	EKG or ECG lead Electrocardiography Electrocardiogram Electrode placements	Physician Healthcare Health Professionals	Education Learning

Appendix B

Literature Search Log

Search date	Database or search engine	Search strategy	Limits applied	Number of citations found/kept	Rationale for inclusion/exclusion of items
09/24/22	PubMed	EKG lead placement AND education AND (healthcare provider OR nurse anesthetist OR hospital personnel) (("electrocardiography"[MeSH Terms] OR "electrocardiography"[All Fields] OR "ekg"[All Fields]) AND ("lead"[MeSH Terms] OR "lead"[All Fields]) AND ("placement"[All Fields] OR "placements"[All Fields]) AND ("educability"[All Fields] OR "educable"[All Fields] OR "educates"[All Fields] OR "education"[MeSH Subheading] OR "education"[All Fields] OR "educational status"[MeSH Terms] OR ("educational"[All Fields] AND "status"[All Fields]) OR "educational status"[All Fields] OR "education"[MeSH Terms] OR "education s"[All Fields] OR "educational"[All Fields] OR "educative"[All Fields] OR "educator"[All Fields] OR "educator s"[All Fields] OR "educators"[All Fields] OR "teaching"[MeSH Terms] OR "teaching"[All Fields] OR "educate"[All Fields] OR "educated"[All Fields] OR "educating"[All Fields] OR "educations"[All Fields]) AND ("health personnel"[MeSH Terms] OR ("health"[All Fields] AND "personnel"[All Fields]) OR "health personnel"[All Fields] OR ("healthcare"[All Fields] AND "provider"[All Fields]) OR "healthcare provider"[All Fields] OR ("nurse anaesthetist"[All Fields] OR "nurse anesthetists"[MeSH Terms] OR ("nurse"[All Fields] AND "anesthetists"[All Fields]) OR "nurse anesthetists"[All Fields] OR ("nurse"[All Fields] AND "anesthetist"[All Fields]) OR "nurse anesthetist"[All Fields]) OR ("personnel, hospital"[MeSH Terms] OR ("personnel"[All Fields] AND "hospital"[All Fields]) OR "hospital personnel"[All Fields] OR ("hospital"[All Fields] AND "personnel"[All Fields])))) AND (2007/1/1:2022/9/24[pdat])	Peer reviewed, 2007-2022	Found: 14 Kept: 10	8 items included due to topics being relevant to DNP project. 1 item excluded due to it being about paramedic education outside of a hospital setting, another excluded due to its subject surrounding interpretation, not placement
09/24/22	CINAHL	((MH "Electrodes") OR (MH "Electrocardiography") OR "EKG lead placement") AND ((MH "Health	Peer reviewed,	Found: 132 Kept: 0	No items included due to not be applicable to DNP

		Personnel") OR (MH "Anesthesia") OR (MH "Anesthesia Nursing") OR (MH "Nursing Staff, Hospital") OR (MH "Nurse Anesthetists") OR (MH "Anesthetists"))	2012-2022		topic, more focused on ECG interpretation or other non-related topics.
09/24/22	Google Scholar	EKG lead placement AND education AND (healthcare provider OR nurse anesthetist OR hospital personnel)	2021-2022 Review articles	Found; 1,210 Kept: 0 10 pages searched	None included due to lack of relevance to DNP topic Findings were either focused on other aspect of EC monitoring or were not related to topic at all.

Appendix C

Literature Matrix

Year	Author, Title, Journal	Purpose & Conceptual Framework or Model	Design and Level of Evidence	Setting	Sample	Tool/s and/or Intervention/s	Results
2021	Sanchez, J., Farasat, M, Levy, A., Douglas, I., Stauffer, B., Tzou, W., & West, J. (2021). A novel approach to electrocardiography in the prone patient. *Heart Rhythm O2, 2(*1), 107-109.	Purpose: To determine the accuracy of ECG waveforms in prone patients No conceptual framework or model noted	Design: ECG, prone, lead placement, alternative position Level III: quasi-experimental	Clinical setting in Colorado	Twenty volunteers were recruited from within staff at the institution.	Volunteers were given a traditional ECG in the standard position, followed by an ECG while in the prone position with alternative lead placement on the back.	Morphology between the ECGs was compared and found to have high concordance (correlation) between most leads except the anteroseptal leads (V1-V3). So, the prone ECG be a reliable means for monitoring when the patient is in the prone position.
2021	Romero, J., Lakkireddy, D., Alviz, I., Rocca, D., Natale, A., & Biase, L. (2021). Interpretation of prone-position 12-lead surface electrocardiogram and main differences compared to supine position ECGS: Insights from a case-control study. *Heart Rhythm, 18*(8).	Purpose: To compare prone position ECGs to supine position ECGs No conceptual framework or model noted	Design: prone, ECGs, supine, accuracy, monitoring Level III: quasi-experimental	Clinical setting: Multicenter	45 patients selected across multiple clinical sites with COVID-19 were compared to 40 healthy patients	ECGs were taken in both prone and supine positions in both groups, and results were compared.	Mean HR, PR interval, QRS duration, QT, QTc interval, and QRS axis were found to positively correlate between supine and prone positions. The anteroseptal leads in the prone position did not correlate as well as the other leads, as there were prominent Q waves, and T wave conversions or flattening. Still, the prone ECG can be an acceptable alternative for the prone patient.
2020	Giannetta, N., Campagna, G., Muzio, F., Simone, E., Dionisi, S., & Muzio, M. (2020). Accuracy and knowledge in 12-lead ECG placement among nursing students and nurses: A web-	Purpose: To study the effect and application of a web survey for nursing students and nurses in their knowledge on the correct positioning of the 12 lead ECG.	Design: electrocardiography, ECG lead placement, clinical skills, delivery of care, nursing education Level VI: Single	Clinical setting in Italy	Total of 484 nursing students and nurses from a clinical setting	A web survey was given to participants in order to determine their knowledge of ECG lead placement.	Participant knowledge showed room for improvement (mean of 73% accuracy), demonstrating the need for further ECG education.

	based Italian study. *Acta Biomedica (91)*12.	No conceptual framework noted.	descriptive study				
2018	Medani, S., Hensley, M., Bao, N., & Owens, P. (2018). Accuracy in precordial ECG lead placement: improving performance through a peer-led educational intervention. *Journal of Electrocardiology, 51*(1), 50-54.	Purpose: Regular training can be implemented to address incorrect ECG lead placement No conceptual framework noted	Design: Lead placement, educational intervention, diagnostic errors. IV: educational training. DV: lead placement Level III: quasi-experimental. Prospective, hospital based pre- and post-intervention performance analysis study	Clinical: University Hospital Waterford, Ireland	Sample: 2 rounds of 100 participants Sample Method: Random clustered sampling of doctors, nurses, and cardiac technicians	Intervention: Eligible staff members place sticker dots on a mannequin, then received an educational intervention of poster presentations, and the study was repeated 6 months later and results were examined	Post education lead placement had higher accuracy (83%) than the pre-education lead placement (34%).
2018	Sakaguchi, S., Sandberg J., & Benditt, D. (2018). ECG electrode reversals: An opportunity to learn from mistakes. Journal of *Cardiovascular Electrophysiology (29)*5. 806-815.	Purpose: education regarding reversed ECG electrodes No conceptual framework noted	Design: depolarization, electrocardiogram, electrocardiography, lead reversals, potentials Level VII: reports of expert committees	N/A	N/A	N/A	N/A
2017	Funk, M., Fennie, K., Stephens, K., May, J., Winkler C., Drew B. (2017) Association of implementation of practice standards for	Purpose: to determine if Online ECG monitoring education and strategies to change practice can lead to improved	Design: electrocardiography, nursing, outcome assessment, quality of health care, randomized	65 cardiac units in 17 hospitals	Sample: Nurses' knowledge: N=3013 Patients: N=4587 Random sampling	Intervention: 2-part intervention consisted of an online ECG monitoring education program and strategies to implement	Nurses' knowledge significantly improved. There was an improvement in measures of quality care. Patient outcomes showed a significant decrease in in-hospital myocardial infarction rates.

	electrocardiographic monitoring with nurses' knowledge, quality of care, and patient outcome: Findings from the practical use of the latest standards of electrocardiography (PULSE) trial. *Circ Cardiovascular Qualitative Outcomes, (10)*2.	nurses' knowledge, quality of care, and patient outcomes. No conceptual framework noted	controlled trial. Level II: randomized control trial			change in clinical practice. Nurses' knowledge was measured by a 20-item online test. Patient outcomes were measured my mortality, in-hospital myocardial infarction, and death from myocardial infarction. Quality of care measured by accurate electrode placement, accurate rhythm interpretation, appropriate monitoring, and ST-segment monitoring when indicated) This was retested 15 months after initial education.	
2016	DiLibero, J., DeSanto-Madyea, S., & O'Dongohue, S. (2016). Improving accuracy of cardiac electrode placement: Outcomes of clinical nurse specialist practice. *Clinical Nurse Specialist (30)*1, 45-50.	Purpose: facilitate a sustainable improvement of cardiac electrode placement for continuous bedside monitoring in intensive care patients No conceptual framework noted	Design: CNS, ECG electrocardiography, electrode Level III: quasi-experimental. Prospective, hospital based pre- and post-intervention performance analysis study	Clinical: academic medical center in Boston, Massachusetts.	Sample: 62 RNs and 12 PCTs	Education was given regarding ECG placement to staff champions, who then educated other staff.	Assessment accuracy improved quickly throughout intervention period, and postintervention assessment accuracy was retained during a six month follow up.

2015	Khan, G. (2015). A new electrode placement method for obtaining 12-lead ECGs. *Open Heart (9)*1.	Purpose: identify alternative placements for obtaining accurate electrocardiography, specifically for torso leads.	Level II: RCT	City of Ottowa, Canada; cardiology referral centers, laboratory centers	Sample: 651 patients attending Gamma Dynacare laboratory and 135 patients form a cardiology referral center. The patients were randomly allocated to 3 different groups.	Upper limb electrodes were placed on mid-arm, various abdominal sites, and infraclavicular. Lower limb electrodes were placed onto lower abdomen for all 3 groups. Results were obtained and compared.	Electrodes positioned on the mid arm or lower abdomen reveal identical ECG without artifact or loss of inferior or lateral infarcts.
2015	Day, K., Olivia, I., Krupinksi, E., Markus, F. (2015). Identification of 4th intercostal space using sternal notch to xiphoid length for accurate electrocardiogram lead placement. *Journal of Electrocardiography (48*)6.	Purpose: Maintaining accurate lead placement in patients who have obesity or loss of anatomical landmarks. No conceptual framework noted	Design: ECG placement, imaging, sternal notch; intercostal space. Level IV: cohort study	N/A	Sample: 55 adults	55 adult chest computed tomography examinations were reviewed for measurements No intervention	The sternal notch to 4th intercostal space distance was 67% of the sternal notch to xiphoid process length, which may be a helpful measurement to locate the 4th intercostal space when it cannot be found in a physical exam.
2014	Fidler, R.L. (2014). *Determining the ideal electrode configuration for continuous in-hospital ECG monitoring* [Doctoral dissertation, University of California, San Francisco]. *UC San Francisco Electronic Theses and Dissertations.*	Purpose: The Mason-Liker configuration should remain the choice for continuous in-hospital ECG monitoring over the Lund configuration. No conceptual framework noted	Design: Mason-Likar configuration, ECG noise, false alarms, ideal configuration, continuous ECG monitoring IV: mason-likar configuration DV: Quality ECG signal Level I: high quality	Clinical	Size: 100 patients Method: University of California San Francisco Medical Center patients from one adult ICU and one adult PCU over a 6-12 month time interval	Tools: Holter monitor, Hook-up Advisor EK-Pro Intervention: Each subject wore 2 Holter monitors, one in Mason-Likar and other in Lund configuration. ECG signals were sent for blind analysis, and signal quality between the	Mason-Likar configurations spent more time in the “green” than the Lund configuration

			prospective cohort study			two configurations was measured. Signal quality was labeled between green-yellow-red	
2012	Garcia-Niebla, J., Rodriquez-Morales. M., Valle-Racero, J., & Bayes de Luna, A. (2012). Negative P wave in V1 is the key to identifying high placement of V1-V2 electrodes in nonpathological subjects. *American Journal of Medicine, 125*(9), e9-13.	Purpose: to discuss how erroneously high placement of V1-V2 can result in a decreased R wave voltage in V1-V2.	Level VII: reports of expert committees	N/A	N/A	N/A	N/A
2012	Ilg, K., & Lehmann, M. (2012) Importance of recognizing pseudo-septal infarction due to electrocardiographic lead misplacement. *The American Journal of Medicine, (125)*1, 23-27.	Purpose: Improve education of health care personnel regarding accurate lead placement and preventing the misdiagnosis of septal infarction. No conceptual framework noted	Design: Electrocardiogram, myocardial infarction, P wave, precordial leads, quality Level VII: reports of expert committees	N/A	N/A	N/A	The nature of MI misdiagnosis is discussed as well as how to prevent: P wave morphology in lead II can aid the clinician in suspecting erroneous lead placement when septal infarction is suspected.
2008	Rajaganesh, R., Ludlam, C., Francis, S., & Parasramka, S. (2008). Accuracy in ECG lead placement among technicians,	Purpose: Clinicians are generally unaware of proper ECG lead placement. Training should focus on precision of	Design: Lead placement, clinician mistakes, clinical significance Level VI: Single	Clinical: six hospitals	Sample: 119 clinicians involved in patients with cardiac disease	Questionnaire developed for study was used. Diagrams were displayed and subject had to localize anatomical landmarks for	90% of cardiac technicians, 49% of nurses, 31% of physicians (excluding cardiologists) and 16% of cardiologists placed the leads incorrectly. V5 and V6 most often mispositioned. Only assessment, no

	nurses, general physicians, and cardiologists. *International Journal of Clinical Practice 62*(1), 65-70.	lead placement. No conceptual framework noted	descriptive study		10 cardiac technicians, 37 nurses, 52 non-cardiologist physicians, 20 cardiologists	where electrodes V1-V6 should be placed.	intervention. Demonstrated the need for education.
2008	Lancia, M., Cerone, M., Vittorini, P., Romano, S., & Penco, M. (2008). A comparison between EASI system 12-lead ECGs and standard 12-lead ECGs for improved clinical nursing practice. *Journal of Clinical Nursing*, *17*(3), 370-377.	Purpose: 5 cables positioned in EASI mode is a valid alternative for standard 12 lead ECG for detecting rhythm abnormalities No conceptual framework noted	Design: Accuracy of 12-lead, EASI ECG placement, standard ECG placement, patient outcomes Level III: Quasi-experimental	Clinical: Coronary Care Unit	Sample: 97 pairs of standard ECG & EASI mode ECG Sample method: Nonrandom convenience sampling. 13 patients admitted consecutively in a coronary unite for myocardial infarction.	Intervention: 13 patients underwent daily recording of 12 lead ECG using the standard ECG and EASI ECG. The samples were compared.	It was found that in the coronary care unit, continuous ECG monitoring with the EASI mode is a valid alternative to the standard 12 lead ECG for rhythm abnormality detection and for acute myocardial infarction assessment
2007	Kligfield, P., Gettes, L., Bailey, J., Childers, R., Deal, B., Hancock, W., Herpen, G., Kors, A., Mcfarlane, P., Mirvis, D., Palm, O., & Wagner, S. (2007). Recommendations for the standardization and interpretation of the electrocardiogram. *Circulation*, *115*(10), 1306-1324.	Purpose: Describe improvements in lead placement, recording methods, and waveform presentation that can ultimately be used to improve ECG standards of practice No conceptual framework noted	Design: Lead placement, use of technology, ECG signal processing, improving ECG processes Level VII: reports of expert committees	N/A	N/A	N/A	Details history of ECG use and how it has changed over time. Contains many recommendations for improving ECG processing

1995	Ide, B. (1995). Bedside electrocardiographic assessment. *The Journal of Cardiovascular Nursing*, *9*(4).	Landmark Study Purpose: Accurate lead placement and clinical knowledge are vital for proper ECG interpretation No conceptual framework noted.	Design: Improving nursing practice, ECG assessment, ECG placement, lead selection, rhythm interpretation Level VII: reports of expert committees	N/A	N/A	N/A	Discussing the importance of nursing practice in optimizing outcomes related to ECG monitoring

Note. Key to abbreviations used in chart: ECG: electrocardiogram; N/A: not applicable; HR: heart rate; RN: registered nurse; PCT: patient care tech; Levels of Evidence adapted from *Evidence-based practice in nursing and healthcare: A guide to best practice* (4th ed.), by B.M. Melnyk and E. Fineout-Overholt, 2019, p.131. Copyright 2019 by Wolters Kluwer.

Appendix D

Approval Forms

CON IRB QI/Program Evaluation Self-Certification Tool Guidance

Name of Project Leader: Lindsay Wright, SRNA

Project Title: DNP Project: ECG Lead Placement

Description of Project and Goals:
The purpose of this quality improvement project is to assess Pre-Operative Care Unit nurses' perceived adequacy of a newly developed reference tool for proper ECG lead placement.

Process: A quick-reference perioperative guide to proper ECG lead placement, based upon accepted national guidelines, will be developed. Pre-op nurses at [redacted] will be asked several questions (through Qualtrics) about their perceptions of the adequacy of their current ECG lead placement resources and practice. An educational video about the use of a newly developed reference tool for proper ECG lead placement will be made available to them, and they will be asked to use the reference tool for two weeks. Upon completions of the two-week utilization period, they will be asked to complete a questionnaire about their perceptions of the adequacy of the proper ECG lead placement reference tool and their current practice. Qualtrics survey software will be used to deliver the intervention link and gather participation perceptions prior to and post implementation of the project. No patient information will be recorded or maintained during this practice.

CON QI Project Approval Questions

Q1: Will the project involve testing an experimental drug, device (including medical software or assays), or biologic (i.e., vaccines, blood products, gene therapy, tissues)?
A1: No
Q2: Has the project received funding (e.g., federal, industry) to be conducted as a human subject research study?
A2: No
Q3: Is this a multi-site project (e.g., there is a coordinating or lead center, more than one site participating, and/or a study-wide protocol)?
A3: No
Q4: Is this a systematic investigation designed with the intent to contribute to generalizable knowledge (e.g., testing a hypothesis, randomization of subjects; comparison of case vs control; observational research; comparative effectiveness research; or comparable criteria in alternative research paradigms)?
A4: No
Q5: Will the results of the project be published, presented, or disseminated outside of the institution or program conducting it?
A5: Yes

Q6: Would the project occur regardless of whether individuals conducting it may benefit professionally from it?

A6: Yes

Q7: Does the project involve "no more than minimal risk" procedures (meaning the probability and magnitude of harm or discomfort anticipated are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routing physical or psychological examinations or tests?)

A7: Yes

Q8: Is the project intended to improve or evaluate the practice or proves within a particular institution or a specific program and falls under well-accepted care practices/guidelines?

Q8: Yes

Center for Research and Grants [redacted]

Quality Improvement Project vs. Human Research Study Determination Form

This worksheet is a guide to help the submitter to determine if a project or study is a quality improvement (QI) project or research study, is involving human subjects or their individually identifiable information, and if IRB approval as defined by the Health and Human Services (HHS) or Food and Drug Administration (FDA) is required. (For more guidance about whether the activity meets the definition of Human Subjects Research see the IRB FAQs or the Human Subject Research Decision Chart)

Please use Microsoft Word to complete this form providing answers below. For signatures, please hand sign or convert into a PDF file and electronically sign. [redacted] please email the form to the [redacted] for Research and Grants (ECUH CRG) at [redacted] A CRG team member will contact you with the results of their review and may reques[redacted] to assist with their determination. The determination will be made in conjunction with the UMCIRB office.

Project Title: CRNA DNP Project: ECG Lead Placement		
Funding Source: None		
Project Leader Name: Lindsay Bruening Wright, BSN, SRNA/ Travis Chabo, PhD, CRNA ☐ **Ed.D.** ☐ **J.D.** ☐ **M.D.** ☐ **Ph.D.** ☐ **Pharm.D.** ☒ **R.N.** ☐ **Other(specify):**		
Job Title [redacted] SRNA/ [redacted] CRNA Faculty	**Phone:** [redacted]	**Email:** chabot14@ecu.edu
	Primary Contact (If different from Project Leader):	
	Phone: [redacted]	**Email:** brueningl21@students.ecu.edu

Key Personnel/ Project Team members:

Name and Degree:	Department: (Affiliation if other than [redacted])	Email:
	[redacted]	

QI/QA Assessment Checklist:

Consideration	Question	Yes	No
PURPOSE	Is the PRIMARY purpose of the project/study to: • IMPROVE care right now for the next patient? OR • IMPROVE operations outcomes, efficiency, cost, patient/staff satisfaction, etc.?	☒	☐
RATIONALE 1	The project/study falls under well-accepted care practices/guidelines or is there sufficient evidence for this mode or approach to support implementing this activity or to create practice change, based on: • literature • consensus statements, or consensus among clinician team	☒	☐
RATIONALE 2	The project/study would be carried out even if there was no possibility of publication in a journal or presentation at an academic meeting. (**Please note that answering "Yes" to this statement does not preclude publication of a quality activity.) **<u>Of note, quality must not be published as if it is research!</u>**	☒	☐
METHODS 1	Are the proposed methods flexible and customizable, and do they incorporate rapid evaluation, feedback and incremental changes?	☒	☐
METHODS 2	Are patients/subjects randomized into different intervention groups in order to enhance confidence in differences that might be obscured by nonrandom selection? (Control group, Randomization, Fixed protocol Methods)	☐	☒
METHODS 3	Will there be delayed or ineffective feedback of data from monitoring the implementation of changes? (For example to avoid biasing the interpretation of data)	☐	☒
METHODS 4	Is the Protocol fixed with fixed goal, methodology, population, and time period?	☐	☒
RISK	The project/study involves no more than minimal risk procedures meaning the probability and magnitude of harm or discomfort anticipated are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.	☒	☐
PARTICIPANTS	Will the project/study only involve patients/subjects who are ordinarily seen, cared for, or work in the setting where the activity will take place?	☒	☐
FUNDING	Is the project/study funded by any of the following? • An outside organization with an interest in the results • A manufacturer with an interest in the outcome of the project relevant to its products • A non-profit foundation that typically funds research, or by internal research accounts	☐	☒

If all of the check marks are inside the shaded gray boxes, then the project/study is very likely QI and not human subject research. Projects that are not human subject research do not need review by the IRB.

In order to assess whether your project meets the definition of human subject research requiring IRB review or may qualify as a quality improvement/assurance activity, please provide the following information:

1. Project or Study Summary:

Please provide a **summary of the purpose and procedures** as well address all of the following:
The purpose of this quality improvement project is to assess nurses' perceptions of adequacy of a newly developed ECG reference guide.
A quick reference ECG lead placement guide, based upon accepted national guidelines, will be developed. Nurses a[redacted] will be asked several questions (through Qualtrics) about their perceptions of the adequacy of their currently used ECG lead placement practice. An educational video about the use of the newly developed reference tool will be made available to them, and they will be asked to use the guide for two weeks. Upon completion of the two-week utilization period, they will be asked to complete a questionnaire about their perceptions of the adequacy of the guide. Qualtrics survey software will be used to gather the participant perceptions of acceptability and adequacy of the intervention prior to and post implementation of the project. No patient information will be recorded or maintained during this project.

a) **The project's primary purpose:** This DNP project will assess the perceived efficacy of a standardized reference tool designed to streamline EKG lead placement and increase consistency across all disciplines in the perioperative setting. EKG lead placement will include standard, 6-lead placement and alternative placement required for varying surgical procedures and positioning.

b) **The project design:** The project will consist of a single Plan, Do, Study, Act cycle using a pre- and post-intervention survey design

c) **Any interaction or intervention with humans**: Nurse participants will be contacted via email and asked to complete a pre-survey and then utilize an information tool based on current evidence that aligns with practices currently accepted within the facility to support their practice regarding ECG lead placement. After two weeks they will then be asked to complete a post-survey addressing their perceptions of the intervention and their own practice. The primary researcher will be available electronically, by phone, or by email to consult with participants as needed.

d) **A description of the methods that will be used and if they are standard or untested**: The intervention for this project will be a newly created informational tool based on current evidence and falls within current accepted practice standards within the facility.

e) **Specify where the data will come from and your methods for obtaining this data -please specify who/where (i.e. CRG will provide you with the data, or someone from a specific department will provide you with the data, or you will pull it yourself)**: Data will be gathered directly from participants through completion of Qualtrics pre- and post-surveys delivered and completed electronically.

f) **Specify what data will be used and any dates associated with when that data was originally collected (i.e Patient Name, Diagnosis, Age, Sex), *If applicable, please attach your data collection sheet: Aside from participants emails, no identifiable data will be gathered*.** Data of interest is participant opinions and perceptions of practice and the newly developed informational tool.

g) **Where will the data (paper and electronic) for your project be stored? Please specify how it will be secured to protect privacy and maintain confidentiality. For paper data, please provide physical location such as building name and room number and that it will be kept behind double lock and key. For electronic data, please provide the file path and folder name network drive where data will be stored and specify that it is secure/encrypted/password protected. If using other storage location, please provide specific details: All data will be gathered using Qualtrics survey software then transferred to Excel for analysis.** The only identifying information utilized or gathered will be email and IP addresses. Qualtrics survey software is accessed through[redacted] and involves multifactorial password protection. Data in Excel will be on a password protected personal laptop. Email and IP addresses will be deleted from Excel files after both surveys are completed and analysis of results begins.

h) **Please specify how long data will be stored after the study is complete? (Keep in mind that data collected/generated during the course of the project that includes protected health information (PHI) should have identifiers removed at the earliest opportunity.)** No PHI will be collected for this project. Data will be stored in Qualtrics and in Excel files (de-identified) until student graduation, anticipated to be in spring of 2024.

i) **Please specify how the collected data will be used (internal/external reports, publishing, posters, etc.) and list name(s) of person responsible for de-identification of data before dissemination**. The de-identified data will be analyzed with results shared via a poster presentation to the [redacted] Nurse Anesthesia Programs students and faculty, with participants invited to watch the presentation remotely. If requested, a presentation of results to the participating department will be provided. Additionally, analysis of results will be addressed in a DNP Project Paper, completion of which is required for program graduation. This paper will be posted in the [redacted] digital repository, The Scholarship. Lindsay Bruening Wright will be responsible for de-identification of all data prior to dissemination.

Please use this space above or **attach a** separate **summary and/or any other additional documentation describing your project**.

2. If the Primary purpose of your project is for QI, have you obtained approval from the [redacted] operational leader within your department or health system:

☐ **No [STOP. Please contact the appropriate operational leader for approval before proceeding.]**

☒ **Yes** [Please specify here whom and obtain their signature in the signature section below]

[redacted] **Operational Mgr/Leader Name:** ___[redacted]___

[redacted]

[redacted] **Operational Mgr/Leader Signature** **Date**

(Part 11 Compliant Electronic Signatures Acceptable-i.e. AdobeSign or DocuSign)

Please note:

- By submitting your proposed project/study for QI determination you are certifying that if the project/study is established to qualify as QI project, you and your Department would be comfortable with the following statement in any publications regarding this project: "This project was reviewed and determined to qualify as quality improvement by the [redacted] Center for Research and Grants."
- If you are submitting a Poster to Media Services, you will also need to submit this Quality Determination Form or IRB Approval to Media Services for printing.
- If the [redacted] CRG determines the activity is not human subject research, then any presentation, publication, etc. should not refer to the activity as "human subject research," "exempt research," or "expedited research."

Attestation of Understanding

My signature below indicates that I fully understand that HIPAA Privacy standards as they apply to Quality Projects involving Protected Health Information and patient medical records as outlined below.

Under HIPAA's minimum necessary provisions [redacted] must make reasonable efforts to limit PHI to the minimum necessary to accomplish the purpose of the use, disclosure or request.

Under HIPAA, a Covered Entity (i.e. [redacted]) can disclose PHI to another CE (i.e. BSOM) for the following subset of health care operations activities of the recipient CE without needing patient consent:

- Conducting quality assessment and improvement activities
- Developing clinical guidelines
- Conducting patient safety activities as defined in applicable regulations
- Conducting population-based activities relating to improving health or reducing health care cost

Identified [redacted] healthcare data utilized in this project should not be shared outside of the CE without a fully executed data use/sharing agreement. [redacted] leadership reserves the opportunity to review all articles for dissemination/ publication for which [redacted] healthcare data has been utilized and that the content is being disseminated in the appropriate manner as a quality initiative, not resembling research in any context.

[redacted]

Project Leader Signature **Date**

(Part 11 Compliant Electronic Signatures Acceptable-i.e. AdobeSign or DocuSign)

-----------------------------------for ECU Health CRG Use Only--------------------------------

NHSR vs. HSR Determination:

☐ **Not Human Subject Research:** The ECUH CRG has determined that based on the description of the project/study, approval by the IRB is not necessary. Any changes or modifications to this project may be discussed with the ECUH CRG at that time to ensure those changes do not elevate the project to human research that would need IRB approval.

☐ **Human Subject Research:** This project/study requires review by the IRB prior to initiation. An application in the electronic IRB submission system should be submitted.

Approval Signatures:

ECUH CRG Reviewer: [redacted] **Date:** [redacted]

UMCIRB Office Staff Reviewe[redacted] **Date:** [redacted]

Appendix E

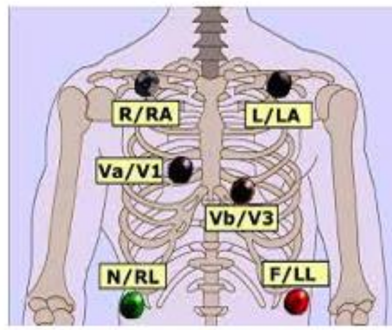
Flyer to Participants

Appendix F

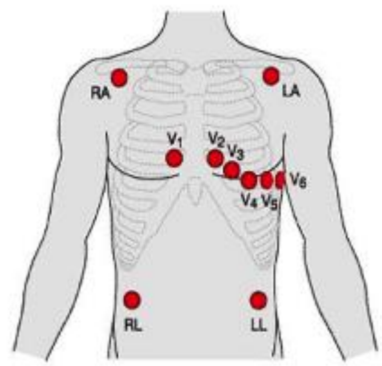
ECG Lead Reference Tool

[redacted] ECG Lead Placement [redacted]

Electrode	Color	Position
RA	White	Right Arm
LA	Black	Left Arm
RL	Green	Right Leg
LL	Red	Left Leg
Va/V1	Red	Sternal Edge Right 4th ICS
Vb/V3	Green	Midway between sternal edge Left 4th ICS and MCL Left 5th ICS



Electrode	Color	Position
RA	White	Right Arm
LA	Black	Left Arm
RL	Green	Right Leg
LL	Red	Left Leg
V1	Red	Sternal Edge Right 4th ICS
V2	Yellow	Sternal Edge Left 4th ICS
V3	Green	Midway between V2 and V3
V4	Blue	Mid-Clavicular Line Left 5th ICS
V5	Orange	Between V4 and V6 Left 5th ICS
V6	Purple	Mid-Axillary Line Left 5th ICS

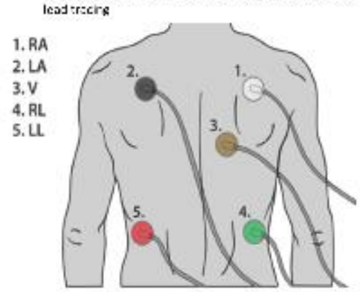


Right-Sided Electrode Placement

- When right sided ischemia is suspected a right sided ECG can be performed for further diagnosis
- A complete set of right sided leads is obtained by placing leads V1-6 in a mirror image position on the right side of the chest
- It can be simpler to leave V1 and V2 in their usual positions and just transfer leads V3-6 to the right side of the chest i.e. V3R to V6R

Prone ECG Lead Placement

- A prone ECG lead waveform is obtained by placing leads in a mirror image position on the back
- While this is a five-lead tracing, the additional V3 lead may also be utilized in the mirror image position for a 6-lead tracing



Appendix G

Pre- and Post-Surveys

Pre-Intervention Survey Questions

1. Did you receive formal training on ECG lead placement as part of the onboarding process for your discipline?
   a. Yes
   b. No
   c. I don’t know
2. How confident do you feel placing ECG leads accurately in standard and alternative positions?

Supine	Not able to place	Not confident	Neutral	Somewhat confident	Confident
Prone	Not able to place	Not confident	Neutral	Somewhat confident	Confident
CV surgery	Not able to place	Not confident	Neutral	Somewhat confident	Confident
Abdominal/laparoscopic surgery	Not able to place	Not confident	Neutral	Somewhat confident	Confident

3. How often do you experience artifact/incorrect morphology with your current ECG lead placement practice?
   a. Never
   b. Not often
   c. Sometimes/neutral
   d. Somewhat often
   e. Very often
4. How often do you adjust ECG lead placement for body habitus, position, dressings, etc. to achieve an acceptable ECG tracing?
   a. Never
   b. Not often
   c. Sometimes/neutral
   d. Somewhat often
   e. Very often
5. How often do you receive patients with inaccurate ECG lead placement?

a. Never
b. Not often
c. Sometimes/neutral
d. Somewhat often
e. Very often

6. Do you currently use standardized methods for ECG lead placement?
   a. Never
   b. Not often
   c. Sometimes/neutral
   d. Somewhat often
   e. Very often
7. Do you believe the quality of patient care could be improved with more accurate ECG lead placement?
   a. Strongly disagree
   b. Disagree
   c. Neutral
   d. Agree
   e. Strongly Agree

Post Intervention Questions

1. How confident do you now feel placing ECG leads accurately in standard and alternative positions?

Supine	Not able to place	Not confident	Neutral	Somewhat confident	Confident
Prone	Not able to place	Not confident	Neutral	Somewhat confident	Confident
CV surgery	Not able to place	Not confident	Neutral	Somewhat confident	Confident
Abdominal/laparoscopic surgery	Not able to place	Not confident	Neutral	Somewhat confident	Confident

2. How often did you adjust placement for body habitus, position, dressings, poor ECG waveform etc. since receive the reference tool?
   a. Never

b. Not often
c. Sometimes/neutral
d. Somewhat often
e. Very often

3. How often have you experience artifact/incorrect morphology with ECG lead placement practice since receiving the tool?
    a. Never
    b. Not often
    c. Sometimes/neutral
    d. Somewhat often
    e. Very often
4. How likely are you to continue to use this reference tool in the future when applying ECG leads?
    a. Never
    b. Not likely
    c. Neutral
    d. Somewhat likely
    e. Very likely
5. This reference tool is easily accessible
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
6. How often did you use this reference tool in your practice since receiving it?
    a. Never
    b. Not often
    c. Sometimes/neutral
    d. Somewhat often

    e. Very often

7. About how much time did it take to reference this reference tool in your daily practice?
    a. Less than 1 minute
    b. 1-2 minutes
    c. 3-5 minutes
    d. Greater than 5 minutes
8. This reference tool improved the quality of patient care I delivered
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
9. After using the reference tool and participating in this QI project, do you think an annual continuing education module on ECG lead placement would improve patient care?
    a. Yes
    b. No
    c. I don’t know
10. Do you have feedback or suggestions that haven’t already been asked?
    a. [Free text reply]

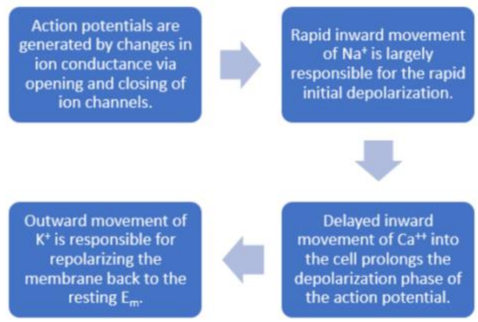
Appendix H

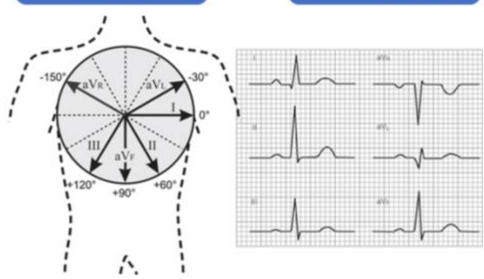
PowerPoint Document

[redacted] ECG Lead Placement [redacted]

Electrophysiology Basics of ECG

- A wave of depolarization traveling toward a positive recording electrode displays a positive voltage on the ECG tracing.
- A wave of repolarization moving away from a positive recording electrode displays a positive ECG voltage.
- The voltage is negative if the depolarization wave is moving away from the positive recording electrodes or a repolarization wave is moving toward the electrode.
- Depolarization or repolarization waves traveling perpendicular to the lead axis of a positive recording electrode display no net voltage.
- The magnitude of the recorded voltage is related to the mass of the muscle undergoing depolarization or repolarization.





[redacted] ECG Lead Placement [redacted]

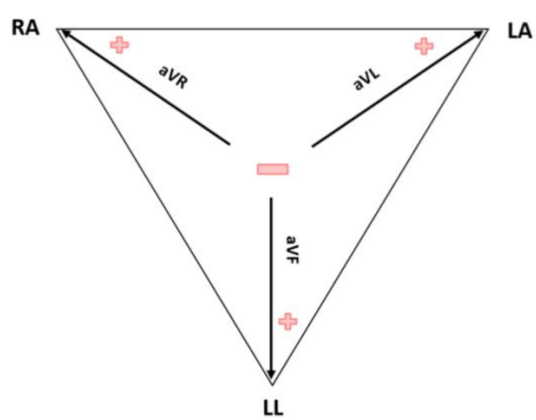
Basics of ECG Monitoring

There are 3 type of leads in typical ECG waveforms:

- Unipolar /Augmented leads
  - aVR, aVL, aVF
- Bipolar leads
  - Lead I, Lead II, Lead III
- Precordial / Chest Leads
  - V1,V2,V3,V4,V5,V6

Lead groupings are based on areas of the heart they examine:

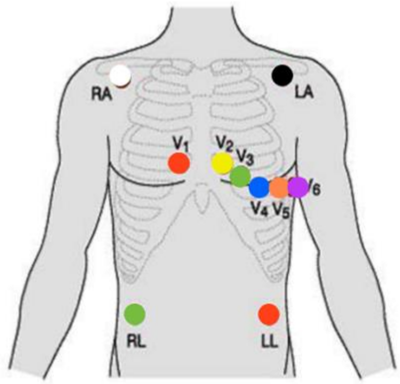
- Inferior: leads II, III, and aVF
- Antero-septal: leads VI and V2
- Anterior: leads V3 and V4
- Lateral: leads I, aVL, V5, and V6



[redacted] ECG Lead Placement [redacted]

Standard 12-Lead ECG Placement

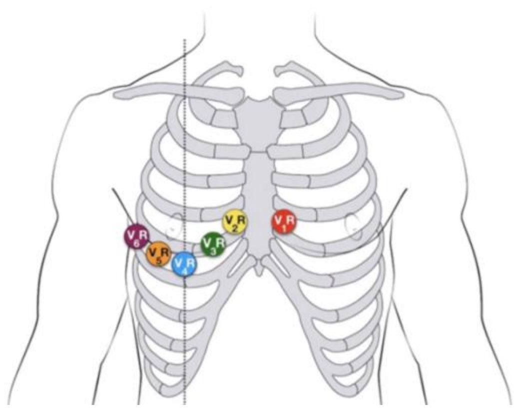
Electrode	Color	Position
RA	White	Right Arm
LA	Black	Left Arm
RL	Green	Right Leg
LL	Red	Left Leg
V1	Red	Sternal Edge Right 4th ICS
V2	Yellow	Sternal Edge Left 4th ICS
V3	Green	Midway between V2 and V4
V4	Blue	Mid-Clavicular Line Left 5th ICS
V5	Orange	Between V4 and V6 Left 5th ICS
V6	Purple	Mid-Axillary Line Left 5th ICS



[redacted] ECG Lead Placement [redacted]

Right-Sided Electrode Placement

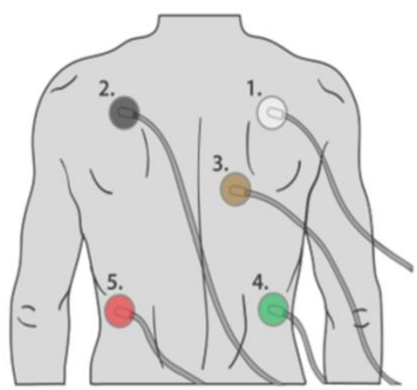
- When right sided ischemia is suspected a right sided ECG can be performed for further diagnosis
- A complete set of right sided leads is obtained by placing leads V1-6 in a mirror image position on the right side of the chest
- It can be simpler to leave V1 and V2 in their usual positions and just transfer leads V3-6 to the right side of the chest (i.e. V3R to V6R



Prone ECG Lead Placement

- A prone ECG lead waveform is obtained by placing leads in a mirror image position on the back
- While this is a five-lead tracing, the additional V3 lead may also be utilized in the mirror image position for a 6-lead tracing

1. RA
2. LA
3. V
4. RL
5. LL



[redacted] ECG Lead Placement Reference Tool [redacted]

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